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Procedia Engineering 24 (2011) 604 – 609

**Procedia
Engineering**

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2011 International Conference on Advances in Engineering

Study on Location Adjustment Model of Store Area in Distribution Center Based on Shortest Picking Time

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Abstract

In order to solve the problem that the work efficiency in distribution center becomes low because of the unreasonable store area location, this paper studies the location adjustment model of store area in distribution center. The store area location 0-1 integer-programming model is established with the shortest total picking time as target function, store capacity and picking points as constraint conditions and a heuristic method is provided for calculating. The practical example shows that the proposed method to adjust store area location is reasonable so as to prove the validity of the location adjustment model.

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Selection and/or peer review under responsibility of ICAE 2011

Keywords: distribution center, store area location, picking time, 0-1 integer programming model, heuristic method*

1. Introduction

When distribution center operates a period of time, it may appear some situations, such as some goods does not meet the store requirements in the store area, the work efficiency in some areas is reducing, and some items' quantity demanded reduces, and so on. The original store location of these items will become unreasonable and affect the whole operation efficiency of distribution center. Therefore, the store location needs to readjust.

There has been some research about location of store area in distribution center at home and abroad. Jukka Korpela put forward to locate items based on sku and reduce the effect on order picking^[1]. Chen Dong pointed out that the location problem was a multi-objective optimization problem. Genetic algorithm suited for solving multi-objective optimization problems. It had simple operation and robust characteristics^[2]. Zuo-Jun put forward that store location model impacted store cost, and put forward the nonlinear model to analyze and obtain the solutions^[3]. Liu Sainan put forward goods-location-coupled

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allocation strategies based on the mapping ^[4], but this strategy was only applicable to the AS/RS store area, would not apply to other store area in distribution center. Linda K analyzed the the cost coefficient during the distribution center operation, including the equipment cost, store cost, and transportation cost. In addition, they established distribution center site-selection model based on cost coefficient ^[5]. Li Shizhen put forward several ways of the picking goods zoning and store zoning. Reasonable zoning could shorten the picking distance and reduce picking time, and improve the distribution center's picking efficiency ^[6].

It is visible that the research about location of store area in distribution center is incomplete and has some limitations. There is not a most-efficient location method of store area. Therefore, the study on the location adjustment model of store area in distribution center has high value.

2. Store area location 0-1 programming model

Store area location adjustment often uses in some situations, such as the planning of a new distribution center's store area and the new goods' store area location, as well as the operation efficiency in some area does not meet the extent of the store area. The goal of adjustment is that the products are all meets the requirements and the store area management can be more orderly. Due to a mass of items involved in adjustment, establish store area mathematical model and solve model to adjust.

2.1. The store area location model

According to the store unit, the store area of distribution center can divide into three big store areas, including the tray store area, box store area, zero goods area. According to the different equipment, each store area can also be subdivided, such as tray area can divide into three-dimensional store area, pallet-racking area, and flat store area. Box store area can divide into clapboard shelf area or the multi-tier rack area. Zero goods area can divide into rapid area and slow area, so that distribution center is consisted of different store areas.

Store area location means to locate each item in the different store area. Using the shortest picking time as target function, store ability and the picking points as constraint conditions, establish the store area location mathematical model. The procedures of establishing mathematical model are as follows:

- Set parameters: set the parameters of each item's existence in each area.

$$X_p^a i = 1, \text{item } i \text{ is in a tray store area}; X_p^a i = 0, \text{item } i \text{ is not in a tray store area} \quad (1)$$

$$X_c^b i = 1, \text{item } i \text{ is in b box store area}; X_c^b i = 0, \text{item } i \text{ is not in b box store area} \quad (2)$$

$$X_B^c i = 1, \text{item } i \text{ is in c zero good area}; X_B^c i = 0, \text{item } i \text{ is not in c zero good area} \quad (3)$$

- Target function: using shortest total picking time of store area in distribution center as the target function.

$$\min T = (T_p^1 + T_p^2 + \dots + T_p^a) + (T_c^1 + T_c^2 + \dots + T_c^b) + (T_B^1 + T_B^2 + \dots + T_B^c) \quad (4)$$

Among them, T_p^a , T_c^b , T_B^c stand respectively for the picking time in a tray store area, b box store area, c zero goods area, the unit is s.

- Constraint conditions

1) The tray store area, box store area, zero goods store area are paratactic store areas, item i can only be stored in one of these areas, so:

$$(X_p^1 i + X_p^2 i + \dots + X_p^a i) + (X_c^1 i + X_c^2 i + \dots + X_c^b i) + (X_B^1 i + X_B^2 i + \dots + X_B^c i) = 1 \quad (5)$$

2) The operation capacity utilization rate in each store must be in the required range

$$\text{Tray store area: } R_P^a \leq R_P^a \leq R_P^a \quad (6)$$

$$\text{Box store area: } R_C^b \leq R_C^b \leq R_C^b \quad (7)$$

$$\text{Zero goods area: } R_B^c \leq R_B^c \leq R_B^c \quad (8)$$

Among them, R_P^a , R_C^b , R_B^c stand respectively for the delivery capacity utilization in tray store area, box store area, zero goods area. The calculation method is outbound quantity divided by outbound ability. R_P^a , R_C^b , R_B^c stand respectively for the minimum delivery capacity utilization in tray store area, box store area, zero goods area. R_P^a , R_C^b , R_B^c stand respectively for the maximum delivery capacity utilization in tray store area, box store area, zero goods area.

3) The store quantity can't exceed the store greatest value; sorting area's sorting point shall not be higher than the highest points

$$\text{Tray store area: } \sum X_P^a i \times S_P^a i \leq S_P^a, i=1,2,\dots,n \quad (9)$$

$$\text{Box store area: } \sum X_C^b i \times S_C^b i \leq S_C^b, i=1,2,\dots,n \quad (10)$$

$$\text{Zero goods area: } \sum X_B^c i \times K_B^c i \leq K_B^c, i=1,2,\dots,n \quad (11)$$

Among them, $S_P^a i$ stands for item i store quantity in a tray store area, the unit is P; $S_C^b i$ stands for item i store quantity in b box store area, the unit is C; $S_B^c i$ stands for item i sku number in c zero goods area.

4) The model is a 0-1 integer programming model, so: $X_P^a i$, $X_C^b i$, $X_B^c i$, all is 0 or 1

• The mathematical model

$$\min T = (T_P^1 + T_P^2 + \dots + T_P^n) + (T_C^1 + T_C^2 + \dots + T_C^n) + (T_B^1 + T_B^2 + \dots + T_B^n)$$

$$\begin{cases} (X_P^1 i + X_P^2 i + \dots + X_P^n i) + (X_C^1 i + X_C^2 i + \dots + X_C^n i) + (X_B^1 i + X_B^2 i + \dots + X_B^n i) = 1, i=1,2,\dots,n \\ R_P^a \leq R_P^a \leq R_P^a; R_C^b \leq R_C^b \leq R_C^b; R_B^c \leq R_B^c \leq R_B^c; \\ \sum X_P^a i \times S_P^a i \leq S_P^a; \sum X_C^b i \times S_C^b i \leq S_C^b; \sum X_B^c i \times K_B^c i \leq K_B^c, i=1,2,\dots,n; \\ X_P^a i, X_C^b i, X_B^c i \text{ are 0 or 1;} \end{cases}$$

2.2. The calculation of operation efficiency index

Whether or not the location adjustment of store area in distribution center is reasonable, it needs some index to verify. This paper uses the picking time as evaluation index. Picking time = picking quantity/single picking quantity \times single picking time:

$$\text{Tray store area picking time: } T_P^a = (\sum X_P^a i \times Q_P^a i) / Q_{P1} \times T_{P1}, i=1,2,\dots,n \quad (12)$$

$$\text{Box store area picking time: } T_C^b = (\sum X_C^b i \times Q_C^b i) / Q_{C1} \times T_{C1}, i=1,2,\dots,n \quad (13)$$

$$\text{Zero store area picking time: } T_B^c = (\sum X_B^c i \times Q_B^c i) / Q_{B1} \times T_{B1}, i=1,2,\dots,n \quad (14)$$

Among them, $Q_P^a i$, $Q_C^b i$, $Q_B^c i$ stand respectively for the item i outbound quantity in a tray store area, b box store area, and c zero goods area. The units are respectively P, C, B; Q_{P1} , Q_{C1} , Q_{B1} stand respectively for the item i single picking tray quantity, box quantity, zero quantity. The units are respectively P, C, B; T_{P1} , T_{C1} , T_{B1} stand respectively for the item i single tray picking time, box picking time, zero picking time. The unit is s.

3. The solution method of store area location model

The location mathematical model of store area in distribution center established in this paper is a single goal 0-1 integer linear programming problem. Combining with classification method in the actual planning of distribution center, use the heuristic method to solve the problem.

Sort outbound quantity value namely IQ of each item from big to small, and then search the boundary point between store areas in the range of constraint conditions. The boundary point Q_1 is the point between tray store area and box store area, the boundary point Q_2 is the point between box store area and zero goods area. Find the the optimal scheme of distribution center store area location which has the minimum picking time sum.

The specific solution steps are as follows:

- 1) Calculate IQ, IQ_P, IQ_C, IQ_B values of each item, and sort IQ value from big to small.
- 2) Select randomly the boundary value Q_1 within the constraint condition as the initial boundary value, and calculate the total picking time T_1 of store areas.
- 3) Select randomly the boundary value Q_2 within the constraint condition, and calculate the total picking time T_2 of store areas.
- 4) If $T_2 > T_1$, the boundary value should be less than or equal to Q_1 . If $T_2 < T_1$, the boundary value should be equal to or greater than Q_1 .
- 5) Circulate as step 4), narrow the choosing range and look for the best solution.
- 6) After determining the boundary point, the parameter values can be confirmed to be 1 or 0, and determine the store area location of each item.

4. Empirical research

Take the data of an actual distribution center as an example, including 3-5 months and 6-8 months, two seasons' order data. In order to locate store area and calculate efficiency index, develop store area location prototype system by using VB programming, import actual data orders for verification.

The distribution center is consisted of three areas, the tray store area, box store area and zero goods area. Tray store area is equipped with stereo warehouse, and covers an area of 2950 square meters, can accommodate 10320 tray goods and has 2580 sorting points. Box store area covers an area of 4830 square meters, and can accommodate 79920 cases of goods. Zero goods area covers an area of 1165 square meters, can accommodate 6400 cases of goods and has 5400 sorting points.

4.1. Store area location

Use 3-5 months' order data as original orders, import the data and process initial location. Use 6-8 months' order data as location adjustment orders, import the data and process location adjustment. The results of initial location and location adjustment show in table 1.

Table 1. The results of initial location and the location adjustment

Item code	initial location		location adjustment	
	Store area	reserves	Store area	reserves
9714	box store area	9C	zero goods area	600B
9670	box store area	128C	tray store area	4P
9638	zero goods area	256B	box store area	12C
...

From the table 1, it shows that some items' store area changes after the location adjustment.

4.2. The effects before and after store area location adjustment

Calculate each index about item number, reserves, outbound quantity, and picking time of the initial location and location adjustment respectively. The results show in the table 2 and table 3.

Table 2. Each index of initial location

Store area	item number	reserves	quantity	Picking time(s/d)	note
tray store area	598	3757P	180P/d	15526	store rate46%, capacity utilization 67%
box store area	1912	20710C	994C/d	12426	store rate 26%, capacity utilization 54%
zero goods area	4005	5046C	252C/d	2512	store rate 74%, capacity utilization 11%
total	/	/		30464	/

Table 3. Each index after location adjustment

Store area	item number	reserves	quantity	Picking time(s/d)	note
tray store area	579	6134P	294P/d	17296	store rate75%, capacity utilization 75%
box store area	1881	21980C	1055C/d	13188	store rate 28%, capacity utilization 57%
zero goods area	3814	4854C	264C/d	2599	store rate 71%, capacity utilization 11%
total	/	/		33083	/

Contrast table 2 and table 3, it can be found that the total picking time increases after location adjustment, this is the result of seasonal changes that the goods requirement in 6-8 months is more than 3-5 months. It is in the reasonable scope. The store utilization ratio and operation capacity utilization are both within constraint condition range. Therefore, the empirical research can verify the validity of the location adjustment method, and realize the effective and reasonable store area location.

5. Conclusion

This paper mainly studies the location adjustment mathematical model of store area in distribution center. Using the total picking time as the target function, store ability and sorting points as constraint conditions, establish store area location adjustment model. In addition, adopt heuristic method to solve the problem. The empirical research uses a certain practical distribution center as a case study, and develops a location adjustment prototype system of store area in distribution center. Import the order data to verify the validation of the location adjustment method.

The location adjustment model of store area in distribution center put forward in this paper has certain reference significance to actual planning and location adjustment of store area in distribution center.

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